Time to imagine space: a chronometric exploration of representational neglect

Paolo Bartolomeo, Anne-Catherine Bachoud-Lévi, Philippe Azouvi, Sylvie Chokron

Neuropsychologia, in press (2005)

Time to imagine space:

A chronometric exploration of

representational neglect

PAOLO BARTOLOMEO[1]

ANNE-CATHERINE BACHOUD-LÉVI[2]

PHILIPPE AZOUVI[3]

SYLVIE CHOKRON[4]

[1] INSERM U610, and Fédération de Neurologie, Hôpital de la Salpêtrière (AP-HP), Paris, France

[2] INSERM U421, Equipe Avenir, Créteil, France, and Service de Neurologie, Hôpital Henri Mondor (AP-HP), Créteil, France

[3] Hôpital Raymond Poincaré (AP-HP), Garches, France, and Université de Versailles Saint Quentin, France

[4] Laboratoire de Psychogie Expérimentale, CNRS UMR 5105, Grenoble, France, and Fondation Ophtalmologique Rothschild, Paris, France

Correspondence to:	Paolo Bartolomeo INSERM U610 Pavillon Claude Bernard Hôpital de la Salpêtrière 47 bd de l'Hôpital F-75013 Paris - France
Telephone:	+33 (0)1 40 78 92 10
Facsimile:	+33 (0)1 42 16 41 95
e-mail:	paolo@broca.inserm.fr

Acknowledgments. Results from this study were presented at the 22nd European Workshop on Cognitive Neuropsychology, Bressanone, Italy, 2004.

Abstract

When describing known places from memory, patients with left spatial neglect may mention more right- than left-sided items, thus showing representational, or imaginal, neglect. This suggests that these patients cannot either build or explore left locations in visual mental imagery. However, in place description there is no guarantee that patients are really employing visual mental imagery abilities, rather than verbal-propositional knowledge. Thus, patients providing symmetrical descriptions might be using other strategies than visual mental imagery. To address this issue, we devised a new test which strongly encourages the use of visual mental imagery. Twelve participants without brain damage and 12 right brain-damaged patients, of whom 7 had visual neglect, were invited to conjure up a visual mental image of the map of France. They subsequently had to state by pressing a left- or a right-sided key whether auditorily presented towns or regions were situated to the left or right of Paris on the imagined map. This provided measures of response time and accuracy for imagined locations. A further task, devised to assess response bias, used the words “left” or “right” as stimuli and the same keypress responses. Controls and non-neglect patients performed symmetrically. Neglect patients were slower for left than for right imagined locations. On single-case analysis, two patients with visual neglect had a greater response time asymmetry on the geographical task than predicted by the response bias task, but with symmetrical accuracy. The dissociation between response times and accuracy suggests that, in these patients, the left side of the mental map of space was not lost, but only “explored” less efficiently.

Abstract word count: 262 words

Keywords. Unilateral neglect, Visual mental imagery, Attention, Brain-damaged patients, Space processing.

1. Introduction

Patients with left spatial neglect may mention more right-sided than left-sided items when describing known places from memory (Brain, 1941; Denny-Brown, Meyer, & Horenstein, 1952). Bisiach and co-workers (1981; 1978) asked left neglect patients to imagine and describe familiar surroundings from memory (the Piazza del Duomo in Milan). Patients omitted to mention left-sided details regardless of the imaginary vantage point that they assumed, thus showing representational, or imaginal, neglect. Bisiach and co-workers proposed that imaginal neglect could either result from "a representational map reduced to one half" (Bisiach et al., 1981, p. 549), or from patients' failure to explore the left part of an intact map, and preferred the amputation hypothesis on grounds of parsimony. Bartolomeo, D'Erme and Gainotti (1994) assessed quantitatively the amount of neglect in 30 right brain-damaged and 30 left brain-damaged patients, tested consecutively on both visuospatial tasks and place description tasks. Three different geographical domains (Roman squares, a map of Europe and the coast of Italy as it could be seen from Sardinia) were used to obtain a sufficient amount of data for analysis. Right brain-damaged patients had a rightward bias in both visual and imaginal tasks, while left brain-damaged patients performed no differently from controls. For right brain-damaged patients, the amount of spatial bias in imaginal tasks correlated with that in visuospatial tasks, thus supporting the hypothesis of a relationship between the two impairments. However, analysis of individual performance revealed that only five of the 17 patients with left visuospatial neglect also showed neglect in the imaginal domain, contrary to the predictions of the map amputation hypothesis. The greater frequency of left neglect in visuospatial than imaginal tasks may result from right visual objects being more likely than right imagined items to capture neglect patients' attention (Bartolomeo & Chokron, 2002b; D'Erme, Robertson, Bartolomeo, Daniele, & Gainotti, 1992; G. Gainotti, D'Erme, & Bartolomeo, 1991; Mark, Kooistra, & Heilman, 1988).

A problem with the description from memory of known places is that abilities other than visual imagery might be used to perform this task. In the Bartolomeo et al.'s study (1994), patients were invited to imagine the places "as if they were in front of them". Despite these instructions, some patients might simply have produced a list of items from verbal semantic memory. If so, imaginal neglect would be underestimated in these tasks, and might thus ultimately appear to be less common than visuospatial neglect, whereas the two disorders would in fact have a similar frequency. On the other hand, even when naming an imagined detail, participants could then verbally associate this detail with others nearby, which would thus be mentioned without being imagined (e.g., when describing a map of France, Paris could be verbally associated with the Seine river). If so, there could be a local inflation of details, which would also complicate estimates of frequency of imaginal neglect. The issue is of theoretical importance, because if imaginal neglect occurs with similar or increased frequency as visual neglect, than the two deficits may stem from a loss of the left part of the mental representation of space (Bisiach, 1993). On the other hand, a larger frequency of visual than imaginal neglect across patients, as suggested by the results reviewed earlier, would rather be consistent with an attentional impairment typically affecting visual objects, and in some cases imagined items too (Bartolomeo et al., 1994). A third possibility is that these two forms of neglect result from entirely different disorders. This possibility is consistent with reports of double dissociations between imaginal and visual neglect (Coslett, 1997; Denis, Beschin, Logie, & Della Sala, 2002; Guariglia, Padovani, Pantano, & Pizzamiglio, 1993; Ortigue et al., 2001), but increases the need for explanation.

But place descriptions have other problems. Idiosyncratic responses are possible, depending, for example, on patients' place of residency or vacation. There is a strong influence of pre-morbid cultural level. Often, too few items are available for statistical analysis. Finally, there is no way to know where patients place the center of their mental images, and consequently on which side the produced items are situated in patients' mental map of space. For example, a lateralized item just imagined could easily become the center of further exploration.

To address these concerns, we developed a response time (RT) task for imagined locations, and compared performance on this task to the widely used task of describing an imaginary map of France (Rode, Perenin, & Boisson, 1995). Participants heard the spoken names of geographical locations (towns and regions of France), and had to press a left- or a right-sided key according to the corresponding imagined location in a mentally-generated map of France with Paris as its center. Participants had no obvious way of performing this task without conjuring up a visual mental image of a map of France, because geographical locations are rarely understood in terms of being situated to the "left" or "right" of Paris. By providing participants with the place names, instead of asking them to list the names, we tried to minimize the influences of particular cultural backgrounds. Our task enabled us to record two measurements, response time and accuracy, that should allow a finer quantitative evaluation of patients' performance than place descriptions. Finally, an imaginary center of the mental map was supplied on each trial by asking participants to start their exploration from the imagined location of Paris. Results of this task should allow one to adjudicate between competing hypotheses of representational neglect. If patients have lost the left part of their mental map of space (Bisiach & Luzzatti, 1978), then left-sided items should either evoke “right” responses or no response at all. If, on the other hand, imaginal neglect results from an impairment of image exploration (Bartolomeo et al., 1994), then patients might respond more slowly to left than to right imagined items, much as they are slowed in responding to left visual targets (Bartolomeo & Chokron, 2002b).

To allow an intuitive matching between stimulus and response, we asked patients to use their right, unaffected hand to press a left- or a right-sided key for the corresponding imagined locations. This, however, introduced a potential problem in the interpretation of the results. Patients with left neglect may show a response bias when asked to press lateralized keys (even if they are close to each other, as in the present study), with faster responses for right-sided keys than for left-sided keys (Behrmann, Black, & Murji, 1995; Làdavas, Farne, Carletti, & Zeloni, 1994). Thus, slower RTs for left-sided imagined locations might in fact originate from a response bias, and not from an imaginal impairment[1]. To address this concern, we asked participants to perform an additional task, employing the same keypress responses but different stimuli. In this control task, participants heard the words “left” or “right”, and had to press the corresponding key. If an asymmetry of performance occurred only in the geographic

---

[1] Using vocal, instead of manual, responses would not eliminate the possibility of response biases. Some neglect patients are unwilling even to utter the word “left”. This may be an additional problem with place description tasks. For example, Brain (1941) described a patient who, “when asked to describe how she would find her way from the tube station to her flat she described this in detail correctly and apparently visualizing the landmarks, but she consistently said *right* instead of *left* for the turning except on one occasion” (p. 259).

task, but not in the response bias task, then it could not be considered to result from a mere response bias.

2. Methods

2.1. Participants

A total of 12 patients with unilateral right hemisphere lesions, at a distance of at least 3 weeks from lesion onset, and 12 age- and education-matched individuals without brain damage (mean age ± SD, 54.42 ± 17.73 years, mean years of schooling ± SD, 12.00 ± 3.33) consented to participate in the study, which was carried out by following the guidelines of the Ethical Committee of the Sainte-Anne Hospital in Paris. Neglect was assessed by using a standardized battery of paper-and-pencil tests (Azouvi et al., 2002). Seven patients were considered as showing signs of left visual neglect, 5 performed within normal limits. Table 1 reports patients' demographical and clinical data.

===============

Table 1 about here

===============

2.2. Description from memory of a map of France

We asked participants to imagine a map of France "like the one shown in TV weather forecasts", and to name as many geographical locations as possible which they imagined "seeing" on the map. Responses given during two minutes were collected and classified as left- or right-sided depending on the items' location with respect to the Paris meridian (Rode et al., 1995). Items situated near the meridian, or items with ambiguous laterality (e.g., the Seine river), were excluded from analysis.

2.3. Geographical RT task

2.3.1. Stimuli

Twenty pairs of geographical locations (names of towns and regions of France) were selected. Each pair consisted of items situated east and west of Paris, in a roughly symmetrical fashion (see Fig. 1 below). Care was taken to choose locations of approximately equal importance, as estimated by the number of inhabitants (mean ± SD, left, 441,567 ± 897,152; right, 455,668 ± 619,475; $t<1$). The items were recorded in a soundproof room by one of the authors (ACBL). The sound files were subsequently edited to eliminate parasitic noise, respiration, stuttering, etcetera, and to ensure a relatively homogeneous onset and offset of each item. Stimuli were matched for duration (left: 720 ± 149 msec; right: 702 ± 130 msec; $t<1$).

2.3.2. Procedure

Stimuli were presented on a Macintosh computer using the SuperLab software. Participants were comfortably seated and wore a pair of headphones. They had their right hand on the computer keyboard, with their index and ring fingers placed on, respectively, the "*k*" and the "*;*" keys of the American keyboard. Before starting, participants were asked to imagine a map of France. Then, on each trial they heard the words "Paris" and, after 200 msec, another French town or region (e.g., "Bordeaux"). Participants were instructed to press the "*k*" key if the second stimulus referred to a location left of Paris, or the "*;*" key if the stimulus indicated a location right of Paris. The intertrial interval was set to 3 seconds starting from the participant's response to the previous trial. A maximum of 5 sec was allowed for response on each trial. Stimuli were given in a random sequence, preceded by six additional practice items, referring to three left locations and three right locations. Responses to practice items were subsequently discarded from analysis. To avoid responses to particular stimuli becoming automatic with practice, each target was presented only once. Accuracy and response times were recorded.

2.4. Response bias RT task

The procedure was identical to that used for the geographical RT task, with the exception that, instead of geographical locations, participants heard the words *gauche* ("left") or *droite* ("right"), and were invited to press the corresponding key as fast as possible. The intertrial interval was set to 1 second. There were 12 left and 12 right stimuli, which were given in random order.

3. Results

3.1. Description from memory of a map of France

Normal participants produced an average of 9.58 items for the left side (SD 3.96), and of 9.75 items for the right side (SD 4.71). No individual participant showed a significant asymmetry on this task (binomial test, all ps > 0.10).

Table 2 reports patients' performance. Only patient N- 4, showing no signs of visual neglect, had a reliable asymmetry of performance on this task (binomial test, $p < 0.03$). The asymmetry resulted from the enumeration in succession of several towns situated in the south-east part of France.

===============

Table 2 and Figure 1 about here

===============

3.2. RT tasks

RTs < 100 msec were excluded as anticipations. This resulted in the exclusion of less than 0.5% of the responses. Figure 1 shows controls' mean RTs for each item of the geographical RT task. Performance was symmetrical concerning both RTs (mean ± SD in msec, left, 737 ± 284; right, 752 ± 146, t < 1) and accuracy (average hits/20 items ± SD, left, 18.50 ± 1.38; right, 18.83 ± 0.94). Remarkably, patients also showed symmetrical accuracy, although at a lower level than controls (neglect: left, 14.29 ± 4.96; right, 14.86 ± 4.02; non-neglect: left, 13.00 ± 2.65; right, 11.80 ± 3.11). Patient N-4, the only participant who mentioned significantly more right-sided than left-sided items on the map description task, had symmetrical performance on the geographical RT task (see Table 2; if anything, there was a tendency to misplace right-sided details to the left, in the opposite sense to that predicted by imaginal neglect). This suggests that her biased performance on map description resulted from one or more of the possible confounds described in the introduction (residence or vacation habits, local inflation of items resulting from verbal association, rightward shift of the center of the visual image consequent upon the description of a right-sided item).

===============

Figure 2 about here

===============

For RTs (Figure 2), we needed to take into account the possibility of a response bias favoring right-sided over left-sided responses (Behrmann et al., 1995; Làdavas et al., 1994). Accuracy on the response bias task was at or near ceiling for all participants. We conducted a repeated-measures analysis of variance on mean RTs with group (controls, neglect, non-neglect), task (geographical, response bias) and side (left, right) as factors. All main effects were significant. Controls were faster than brain-damaged patients, $F(2, 21) = 19.04$, $p < 0.0001$ (Tukey HSD test, controls vs. each of the 2 groups of patients, ps < 0.005; neglect vs. non-neglect patients, $p > 0.32$), the response bias task evoked faster responses that the geographical task, $F(1, 21) = 29.55$, $p < 0.0001$, and right responses were faster than left responses $F(1, 21) = 14.02$, $p = 0.001$. The group interacted with the task, $F(2, 21) = 5.19$, $p = 0.015$, with the side, $F(2, 21) = 7.18$, $p = 0.004$, and, most importantly, with task and side, $F(2, 21) = 4.45$, $p = 0.024$, because neglect patients had the most severe left-right RT asymmetry, and then especially on the geographical task (left–right difference for neglect patients on the geographical task, 563 msec; Tukey HSD test, $p < 0.001$; left–right differences for all the other conditions and groups, ps > 0.53) (see Figure 2). Thus, neglect patients as a group showed an asymmetry of RTs with responses to left-sided imagined items being slower than RTs to right-sided items, consistent with the notion of imaginal neglect. This asymmetry can not be entirely accounted for by a response bias, because neglect patients showed a lesser asymmetry when asked to produce the same responses without using visual mental imagery abilities.

To explore individual patient performances, we normalized each RT by dividing it by the average RT for each patient on each task, then calculated scores of laterality for each patient and task (normalized left – right RTs), and plotted these scores along with the 95% inferential confidence intervals (Tryon, 2001) of the left-right difference for each patient (Figure 3). In this way, one can be 95% confident that intervals which do not cross the horizontal axis at 0 indicate a rightward bias (for positive values) or a leftward bias (for negative values). For each patient, non-overlapping intervals indicate a difference in bias between the two tasks.

===============

Figure 3 about here

===============

Five neglect patients of seven and one non-neglect patient demonstrated a reliable rightward bias on the geographical task. However, only for two patients (N+ 1 and 4) could this bias be confidently attributed to an imaginal impairment, because for the other patients there was substantial overlapping with performance on the motor bias task. The two patients with imaginal bias also had neglect on paper-and pencil tests. Importantly, they had symmetrical accuracy on the geographical RT task (see Table 2).

4. Discussion

We used a response time task to explore imaginal neglect. Participants heard the name of towns or regions of France and pressed the key corresponding to their localization. This task (1) strongly incites participants to conjure up a visual mental image of a geographic map, and discourages strategies based on purely verbal recall of locations; (2) supplies both the center of exploration and the item to be localized on each trial, and is thus less subject to idiosyncratic responses than place descriptions; (3) provides quantitative measures of performance (accuracy and RTs). Thus, the geographical RT task does not suffer from problems affecting place description tasks. It can be used to test hypotheses about imaginal neglect and its relationships with visual neglect, and can be repeated to assess patients’ performance before and after rehabilitation.

Participants found the geographical task more difficult than the response bias task, as shown by longer RTs and higher error rates in the former than in the latter task.

It is sometimes suggested that difficulty may increase biases in neglect patients. Thus, it might be that a mere response bias determined the present pattern of results in neglect patients, including the increased asymmetry of response on the geographical task. However, we deem this possibility implausible, because (1) most of our patients did not show a greater bias on the response bias task than on the geographical task (see Fig. 3), (2) the two forms of biases seemed unrelated, as suggested by the lack of significant correlation between their amounts across patients ($r = 0.24$, $z < 0$, $p>0.45$), and (3) in previous research, motor biases were hardly affected by the difficulty of the task[2].

Denis et al. (2002) proposed other methods to explore imaginal neglect. They presented patients with visual layouts or verbal descriptions of layouts and subsequently asked them to recall the presented material (Halligan, Marshall, & Wade, 1992, had previously proposed a similar technique of recall from verbal description). Neglect

---

[2] For example, Làdavas et al. (1994, Exp. 1) asked neglect patients to respond to visual stimuli by pressing two horizontally aligned adjacent keys. Patients showed slower responses with the left-sided key than with the right-sided key, consistent with a response bias. In a further condition, the keyboard was reversed by 180°. Again patients were slower when pressing the key in the relative left spatial position. Patients found the reversed condition more difficult than the standard condition, as shown by an increased error rate in the reversed condition. However, their asymmetry of response (57 msec) was the same as in the standard condition (56 msec). Another study on motor bias in neglect (Bartolomeo, D'Erme, Perri, & Gainotti, 1998) reported *less* RT asymmetry in a relatively difficult test in which patients had to press left- or right-sided keys in response to central visual stimuli, compared to a much easier task requiring patients to respond with a unique, centrally placed key to lateralized visual targets.

patients reported fewer items from the left than from the right side in both conditions, but especially in the "memory after perception" condition, which resulted in a significant interaction between conditions. However, in the "memory after perception" condition visual neglect could have biased the perceptual apprehension of the visual scene, consistent with the increased neglect demonstrated in this condition. On the other hand, in the "memory after description" condition normal controls also had a tendency to report fewer items from the left than from the right side, which might suggest a task-dependent bias.

Bächtold et al. (1998) visually presented numbers 1 to 11 in the center of the visual field, and found asymmetries of RTs in normal individuals, with faster left-hand RTs for numerals <6 and a right-hand RTs advantage for those >6 for subjects who conceived of the numbers as distances on a ruler, and a reversed asymmetry for subjects who conceived numbers as hours on a clock face. They attributed this pattern of results to a spatial stimulus-response compatibility effect, and suggested that their task could be usefully applied to the study of imaginal neglect. Kukolja et al. (2004) asked normal participants to judge whether the angle of imagined clock hands corresponding to a time visually given as digital numbers (e.g., 06:50) was greater than or less than 90°. Participants had longer RTs and greater error rates when the imagined angle was located in the left hemispace than when it was in the right hemispace, perhaps because they mentally rotated the imaginary minute hand in a clockwise direction starting from the "noon" position. The present RT tasks share with these tasks the advantage of obtaining quantitative measures of performance on a continuous scale, and have the additional advantage of excluding any visual input[3]. The geographical RT task consequently allows an even more clear-cut exploration of imaginal neglect, without any risk of contamination from perceptual neglect.

Our finding of a reliable rightward RT bias in two of seven patients with visual neglect[4], and of no such bias in patients without visual neglect, confirms previous evidence obtained with place descriptions (Bartolomeo et al., 1994), that only about a third of patients with visual neglect demonstrate imaginal neglect too, and that neglect confined to visual mental imagery is a rare occurrence. Group studies (Halsband, Gruhn, & Ettlinger, 1985), the detailed report of two cases (Anderson, 1993), and a

[3] Although the numbers were centrally presented in the tasks devised by Bächtold et al. (1998) and Kukolja et al. (2004), one cannot exclude the possibility that, for example, neglect patients would process more efficiently the right digits than the left digits with multi-digit numbers.

[4] Caution is needed concerning the present estimate of the frequency of imaginal neglect, because imagery and motor biases can co-exist in the same patient, and an imagery bias cannot be excluded in patients showing a bias in both tasks. There is no reason, however, to suppose that an imaginal and a response bias should *interact* with each other, because they are supposed to be distinct deficits. This results from the very definition of a motor bias as a bias independent of perceptual (or, here, imaginal) factors. Following the additive factor logic (Sternberg, 1969), then, in the case of an association of imaginal and motor biases, these biases would add with each other, as in patient N+4 (see Fig. 3). A motor bias without imaginal bias would on the contrary slow ‘left’ responses to a similar extent in both tasks, thus leading to overlapping biases as in patients N+3, N+2 and N+6.

study conducted during intracarotid injection of amobarbital (Manoach, O'Connor, & Weintraub, 1996) also confirmed that visuospatial neglect often occurs without representational neglect. At least some of the rare cases of representational neglect in isolation could originate from selective recovery of visual neglect in patients originally showing an association of visual and imaginal neglect. Patients might learn to endogenously orient their attention to left visual objects (Bartolomeo, 1997, 2000; Bartolomeo, Siéroff, Decaix, & Chokron, 2001), but not to left visual images, which are not usually the object of rehabilitation or of verbal exhortations from the caregivers. Follow-up studies, in which visual and imaginal neglect were repeatedly assessed, show several examples of this pattern of selective recovery (Bartolomeo & Chokron, 2001; Bartolomeo et al., 1994; Coslett, 1989, 1997; Rode, Rossetti, Perenin, & Boisson, 2004)[5].

In their seminal report, Bisiach and Luzzatti (1978) suggested that imaginal neglect could either result from an amputation of patients' mental representation of space, or from patients' inability to explore the left part of an intact map, and preferred the amputation hypothesis. Our result of asymmetrical RTs with symmetrical accuracy

---

[5] In two other cases (Beschin, Cocchini, Della Sala, & Logie, 1997; Ortigue et al., 2001), imaginal neglect appeared to have occurred at disease onset without any signs of visual neglect. Concerning these cases, one may note that patients may sometimes show only subtle signs of visual neglect, whose clinical compensation may occur in a few days (see, e.g., Fig. 5 in Bartolomeo & Chokron, 2001); other patients may demonstrate even milder signs of visual spatial bias (e.g., only on RT tests). We acknowledge, however, that evidence of an isolated imaginal neglect at onset would render our present account less generally applicable (see also the discussion in Marshall & Halligan, 2002).

in the geographical task suggests, instead, that attentional biases resulting in visual neglect (Bartolomeo & Chokron, 2002b) may also operate in visual mental imagery (Bartolomeo & Chokron, 2002a). Consistent with this hypothesis, imaginal neglect can be offset by the same sensory-motor maneuvers which favorably affect visual neglect, such as leftward eye and head turning (Meador, Loring, Bowers, & Heilman, 1987), vestibular stimulation (Rode & Perenin, 1994), and visuomotor adaptation to right-deviating prisms (Rode, Rossetti, & Boisson, 2001). These procedures may act by facilitating leftward orienting of attention (Chokron & Bartolomeo, 1999; Gainotti, 1993). Also the evidence of an asymmetry of REMs during sleep in neglect patients (Doricchi, Guariglia, Paolucci, & Pizzamiglio, 1993) is in agreement with the idea that the attentional bias in neglect need not be restricted to real visual objects. Rather than sharing low-level mechanisms with vision (Kosslyn, Ganis, & Thompson, 2003), visual mental imagery may involve some of the attentional-exploratory mechanisms that are employed in visual behavior (Bartolomeo, 2002; Chokron, Colliot, & Bartolomeo, 2004; Griffin & Nobre, 2003; Thomas, 1999). It may be precisely the utilization of these processes of “active” vision that renders visual mental imagery so similar to “real” visual experience (O'Regan & Noë, 2001). The definition of the exact conditions under which an attentional bias can result in visual neglect only, or spread to mental imagery abilities, constitutes a fascinating challenge for future research.

References

Anderson, B. (1993). Spared awareness for the left side of internal visual images in patients with left-sided extrapersonal neglect. *Neurology, 43*, 213-216.

Azouvi, P., Samuel, C., Louis-Dreyfus, A., Bernati, T., Bartolomeo, P., Beis, J.-M., et al. (2002). Sensitivity of clinical and behavioural tests of spatial neglect after right hemisphere stroke. *Journal of Neurology, Neurosurgery and Psychiatry, 73*(2), 160-166.

Bächtold, D., Baumüller, M., & Brugger, P. (1998). Stimulus-response compatibility in representational space. *Neuropsychologia, 36*(8), 731-735.

Bartolomeo, P. (1997). The novelty effect in recovered hemineglect. *Cortex, 33*(2), 323-332.

Bartolomeo, P. (2000). Inhibitory processes and compensation for spatial bias after right hemisphere damage. *Neuropsychological Rehabilitation, 10*(5), 511-526.

Bartolomeo, P. (2002). The relationship between visual perception and visual mental imagery: a reappraisal of the neuropsychological evidence. *Cortex, 38*(3), 357-378.

Bartolomeo, P., & Chokron, S. (2001). Levels of impairment in unilateral neglect. In F. Boller & J. Grafman (Eds.), *Handbook of Neuropsychology* (2nd ed., Vol. 4, pp. 67-98). Amsterdam: Elsevier Science Publishers.

Bartolomeo, P., & Chokron, S. (2002a). Can we change our vantage point to explore imaginal neglect? (Commentary on Pylyshyn: Mental imagery: In search of a theory). *Behavioral and Brain Sciences, 25*(2), 184-185.

Bartolomeo, P., & Chokron, S. (2002b). Orienting of attention in left unilateral neglect. *Neuroscience and Biobehavioral Reviews, 26*(2), 217-234.

Bartolomeo, P., D'Erme, P., & Gainotti, G. (1994). The relationship between visuospatial and representational neglect. *Neurology, 44*, 1710-1714.

Bartolomeo, P., D'Erme, P., Perri, R., & Gainotti, G. (1998). Perception and action in hemispatial neglect. *Neuropsychologia, 36*(3), 227-237.

Bartolomeo, P., Siéroff, E., Decaix, C., & Chokron, S. (2001). Modulating the attentional bias in unilateral neglect: The effects of the strategic set. *Experimental Brain Research, 137*(3/4), 424-431.

Behrmann, M., Black, S. E., & Murji, S. (1995). Spatial attention in the mental architecture: Evidence from neuropsychology. *Journal of Clinical and Experimental Neuropsychology, 17*(2), 220-242.

Beschin, N., Cocchini, G., Della Sala, S., & Logie, R. (1997). What the eyes perceive, the brain ignores: A case of pure unilateral representational neglect. *Cortex, 33*, 3-26.

Bisiach, E. (1993). Mental representation in unilateral neglect and related disorders. *The Quarterly Journal of Experimental Psychology, 46A*(3), 435-461.

Bisiach, E., Capitani, E., Luzzatti, C., & Perani, D. (1981). Brain and conscious representation of outside reality. *Neuropsychologia, 19*, 543-551.

Bisiach, E., & Luzzatti, C. (1978). Unilateral neglect of representational space. *Cortex, 14*, 129-133.

Brain, R. W. (1941). Visual disorientation with special reference to lesion of the right brain hemisphere. *Brain, 64*, 244-272.

Chokron, S., & Bartolomeo, P. (1999). Réduire expérimentalement la négligence spatiale unilatérale : revue de la littérature et implications théoriques. *Revue de Neuropsychologie, 9*(2-3), 129-165.

Chokron, S., Colliot, P., & Bartolomeo, P. (2004). The role of vision on spatial representations. *Cortex, 40*(2), 281-290.

Coslett, H. B. (1989). Dissociation of attentional mechanisms in vision: evidence from neglect. *Journal of Clinical and Experimental Neuropsychology, 11*(1), 80 (abstract).

Coslett, H. B. (1997). Neglect in vision and visual imagery: A double dissociation. *Brain, 120*, 1163-1171.

Denis, M., Beschin, N., Logie, R. H., & Della Sala, S. (2002). Visual perception and verbal descriptions as sources for generating mental representations: Evidence from representational neglect. *Cognitive Neuropsychology, 19*(2), 97-112.

Denny-Brown, D., Meyer, J. S., & Horenstein, S. (1952). The significance of perceptual rivalry resulting form parietal lesion. *Brain, 75*, 433-471.

D'Erme, P., Robertson, I. H., Bartolomeo, P., Daniele, A., & Gainotti, G. (1992). Early rightwards orienting of attention on simple reaction time performance in patients with left-sided neglect. *Neuropsychologia, 30*(11), 989-1000.

Doricchi, F., Guariglia, C., Paolucci, S., & Pizzamiglio, L. (1993). Disturbances of the rapid eye movements (REMs) of REM sleep in patients with unilateral attentional neglect: clue for the understanding of the functional meaning of REMs. *Electroencephalography and Clinical Neurophysiology, 87*(3), 105-116.

Gainotti, G. (1993). The role of spontaneous eye movements in orienting attention and in unilateral neglect. In I. H. Robertson & J. C. Marshall (Eds.), *Unilateral Neglect: Clinical and Experimental Studies* (pp. 107-122). Hove (UK): Lawrence Erlbaum Associates.

Gainotti, G., D'Erme, P., & Bartolomeo, P. (1991). Early orientation of attention toward the half space ipsilateral to the lesion in patients with unilateral brain damage. *Journal of Neurology, Neurosurgery and Psychiatry, 54*, 1082-1089.

Griffin, I. C., & Nobre, A. C. (2003). Orienting attention to locations in internal representations. *Journal of Cognitive Neuroscience*, *15*(8), 1176-1194.

Guariglia, C., Padovani, A., Pantano, P., & Pizzamiglio, L. (1993). Unilateral neglect restricted to visual imagery. *Nature, 364*, 235-237.

Halligan, P. W., Marshall, J. C., & Wade, D. T. (1992). Contrapositioning in a case of visual neglect. *Neuropsychological Rehabilitation*, *2*(2), 125-135.

Halsband, U., Gruhn, S., & Ettlinger, G. (1985). Unilateral spatial neglect and defective performance in one half of space. *International Journal of Neurosciences*, *28*(3-4), 173-195.

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2003). Mental imagery: against the nihilistic hypothesis. *Trends in Cognitive Sciences*, *7*(3), 109-111.

Kukolja, J., Marshall, J. C., & Fink, G. R. (2004). Judging the angles formed by visible and imaginary clock hands: a study of hemispatial effects in healthy volunteers. *Cortex*, *40*(2), 329-337.

Làdavas, E., Farne, A., Carletti, M., & Zeloni, G. (1994). Neglect determined by the relative location of responses. *Brain*, *117*(Pt 4), 705-714.

Manoach, D. S., O'Connor, M., & Weintraub, S. (1996). Absence of neglect for mental representations during the intracarotid amobarbital procedure. *Archives of Neurology*, *53*(4), 333-336.

Mark, V. W., Kooistra, C. A., & Heilman, K. M. (1988). Hemispatial neglect affected by non-neglected stimuli. *Neurology*, *38*(8), 640-643.

Marshall, J., & Halligan, P. W. (2002). Whoever would have imagined it? Bisiach and Luzzatti (1978) on representational neglect in patients IG and NV. In C. Code, C. W. Wallesch, Y. Joanette & A. Roch Lecours (Eds.), *Classic Cases in Neuropsychology II* (Vol. 2, pp. 272-274). Hove: Taylor & Francis Books Ltd.

Meador, K. J., Loring, D. W., Bowers, D., & Heilman, K. M. (1987). Remote memory and neglect syndrome. *Neurology*, *37*, 522-526.

O'Regan, J. K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences*, *24*(5).

Ortigue, S., Viaud-Delmon, I., Annoni, J. M., Landis, T., Michel, C., Blanke, O., et al. (2001). Pure representational neglect after right thalamic lesion. *Annals of Neurology*, *50*(3), 401-404.

Rode, G., & Perenin, M. T. (1994). Temporary remission of representational hemineglect through vestibular stimulation. *NeuroReport*, *5*, 869-872.

Rode, G., Perenin, M. T., & Boisson, D. (1995). Négligence de l'espace représenté : mise en évidence par l'évocation mentale de la carte de France [Neglect of the representational space: demonstration by mental evocation of the map of France]. *Revue Neurologique*, *151*(3), 161-164.

Rode, G., Rossetti, Y., & Boisson, D. (2001). Prism adaptation improves representational neglect. *Neuropsychologia*, *39*(11), 1250-1254.

Rode, G., Rossetti, Y., Perenin, M. T., & Boisson, D. (2004). Geographic information has to be spatialized to be neglected: a representational neglect case. *Cortex*, *40*(2), 391-397.

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. *Acta Psychologica*, *30*, 276-315.

Thomas, N. J. T. (1999). Are theories of imagery theories of imagination? An active perception approach to conscious mental content. *Cognitive Science, 23*(2), 207-245.

Tryon, W. W. (2001). Evaluating statistical difference, equivalence, and indeterminacy using inferential confidence intervals: an integrated alternative method of conducting null hypothesis statistical tests. *Psychological Methods, 6*(4), 371-386.

Table 1. Patients' demographical and clinical data

Patient	Sex / age / education	Days since onset	Aetiology	Locus of lesion	Line bisection (deviation in mm for 200mm / 100mm lines)	Bells cancellation (number of left/right hits, max 15/15)	Overlapping figures (number of left/right hits, max 10/10)	Landscape drawing (number of omissions)
N+ 1	F / 75 / 11	25	Ischemic	Internal capsule	+8 / -3.5	0 / 5	7 / 10	4
N+ 2	M / 53 / 12	70	Ischemic	T P F	+42.5 / +3	0 / 8	0 / 7	4
N+ 3	M / 66 / 17	183	Ischemic	T P post + subcortical, F	+77 / +13	0 / 3	4 / 10	1
N+ 4	M / 57 / 12	431	Hemorrhagic	BG	+55 / +8	4 / 11	9 / 10	4
N+ 5	M / 32 / 15	33	Hemorrhagic	BG, P sup, O	+8.5 / -1	14 / 15	9 / 10	1
N+ 6	M / 71 / 8	90	Ischemic	T P, subcortical	+8 / +36	0 / 2	0 / 3	4
N+ 7	F / 73 / 8	28	Ischemic	F post, F med, P ant, T sup, Insula	+14.3 / -3.5	15 / 15	0 / 7	4
N- 1	M / 34 / 14	128	Hemorrhagic	T	+9 / +0	11 / 13	10 / 10	0
N- 2	F / 45 / 9	88	Ischemic	T ant, BG, Corona radiata	+5 / +2	15 / 15	10 / 10	0

Table 1 (continued)

Patient	Sex / age / education	Days since onset	Aetiology	Locus of lesion	Line bisection (deviation in mm for 200mm / 100mm lines)	Bells cancellation (number of left/right hits, max 15/15)	Overlapping figures (number of left/right hits, max 10/10)	Landscape drawing (number of omissions)
N- 3	F / 60 / 8	32	Ischemic	P, T-P junction, subcortical	+4.5 / +2.5	15 / 15	10 / 10	0
N- 4	F / 74 / 7	205	Ischemic	Anterior F	+2 / +1	15 / 13	10 / 10	0
N- 5	F / 28 / 12	44	Hemorrhagic	Corona radiata, F	+7 / +3	15 / 15	10 / 10	0

F, frontal; T, temporal ; P, parietal; O, occipital; BG, basal ganglia; sup, superior; ant, anterior; post, posterior; med, medial. For line bisection, positive and negative values indicate, respectively, rightward and leftward deviations.

Table 2. Number of left and right details given by patients when describing the map of France and number of errors (transpositions to the opposite side) and omissions on the geographical RT task

	L DETAILS	*R DETAILS*	*L ERRORS*	*R ERRORS*	*L OMISSIONS*	*R OMISSIONS*
N+ 1	3	7	1	0	3	3
N+ 2	18	15	1	0	0	0
N+ 3	9	3	3	2	3	3
N+ 4	7	6	1	2	0	0
N+ 5	10	8	2	1	1	5
N+ 6	3	4	9	6	3	2
N+ 7	7	7	11	7	2	5
N- 1	3	5	3	3	3	1
N- 2	4	8	9	6	1	0
N- 3	0	2	8	11	0	0
N- 4	4	12	3	9	0	0
N- 5	4	5	3	2	5	9

Figure captions

Figure 1. Controls' mean response times to each item of the geographical RT task.

Figure 2. Performance of normal controls and of right-brain damaged patients with or without visual neglect for left-sided items (hatched bars) and right-sided items (empty bars) on the geographical RT task and on the response bias RT task. Error bars denote 95% confidence intervals.

Figure 3. Laterality scores of each individual patient on the geographical RT task and on the response bias RT task. Positive values, rightward bias; negative values, leftward bias. Error bars denote inferential 95% confidence intervals.

Figure 1

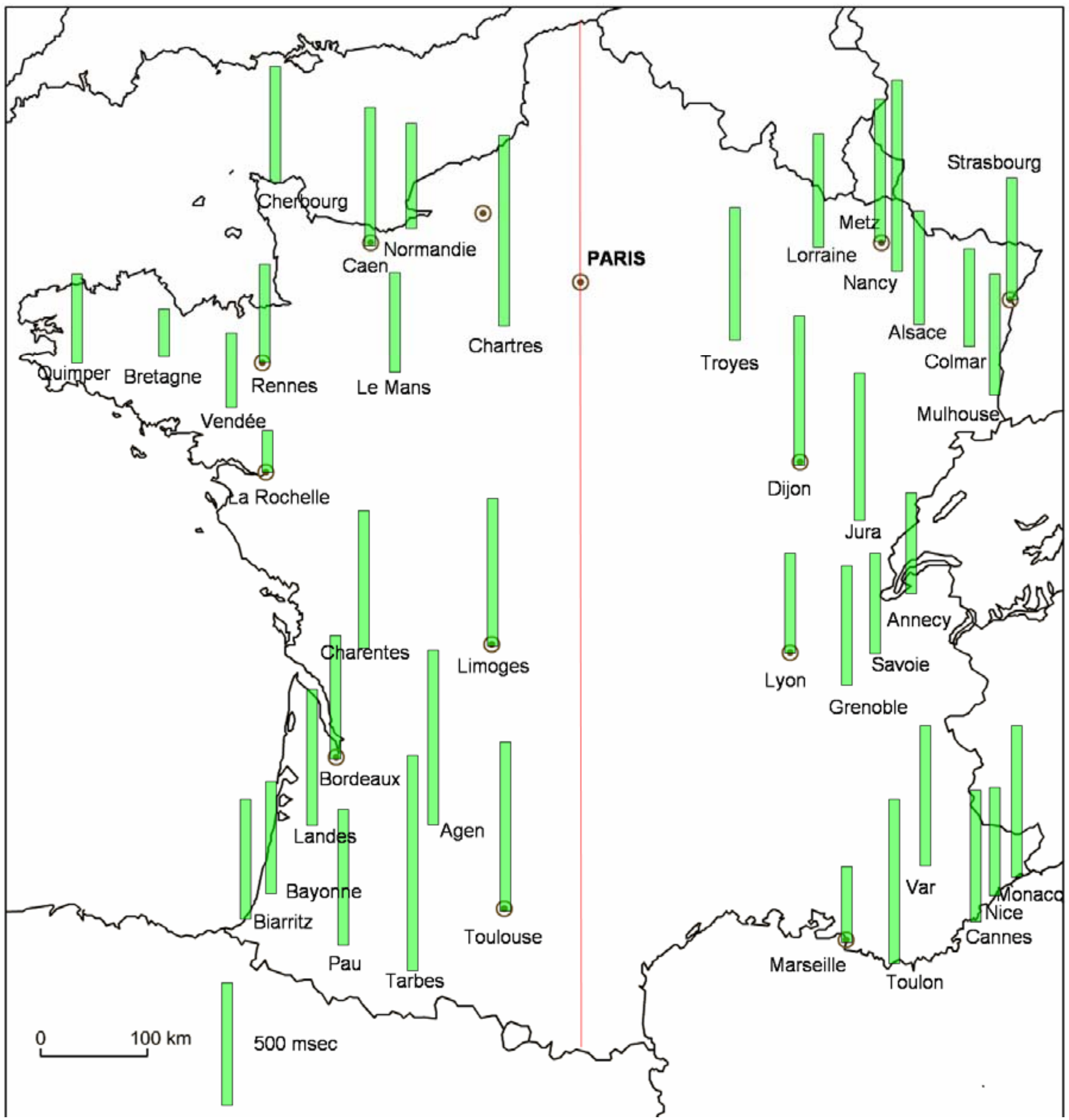

Strasbourg
Metz
Lorraine
Nancy
Alsace
Colmar
Mulhouse
Troyes
Dijon
Jura
Annecy
Savoie
Lyon
Grenoble
PARIS
Cherbourg
Normandie
Caen
Chartres
Quimper
Bretagne
Rennes
Le Mans
Vendée
La Rochelle
Charentes
Limoges
Bordeaux
Landes
Agen
Bayonne
Biarritz
Pau
Tarbes
Toulouse
Marseille
Toulon
Var
Monaco
Nice
Cannes
0
100 km
500 msec

Figure 2

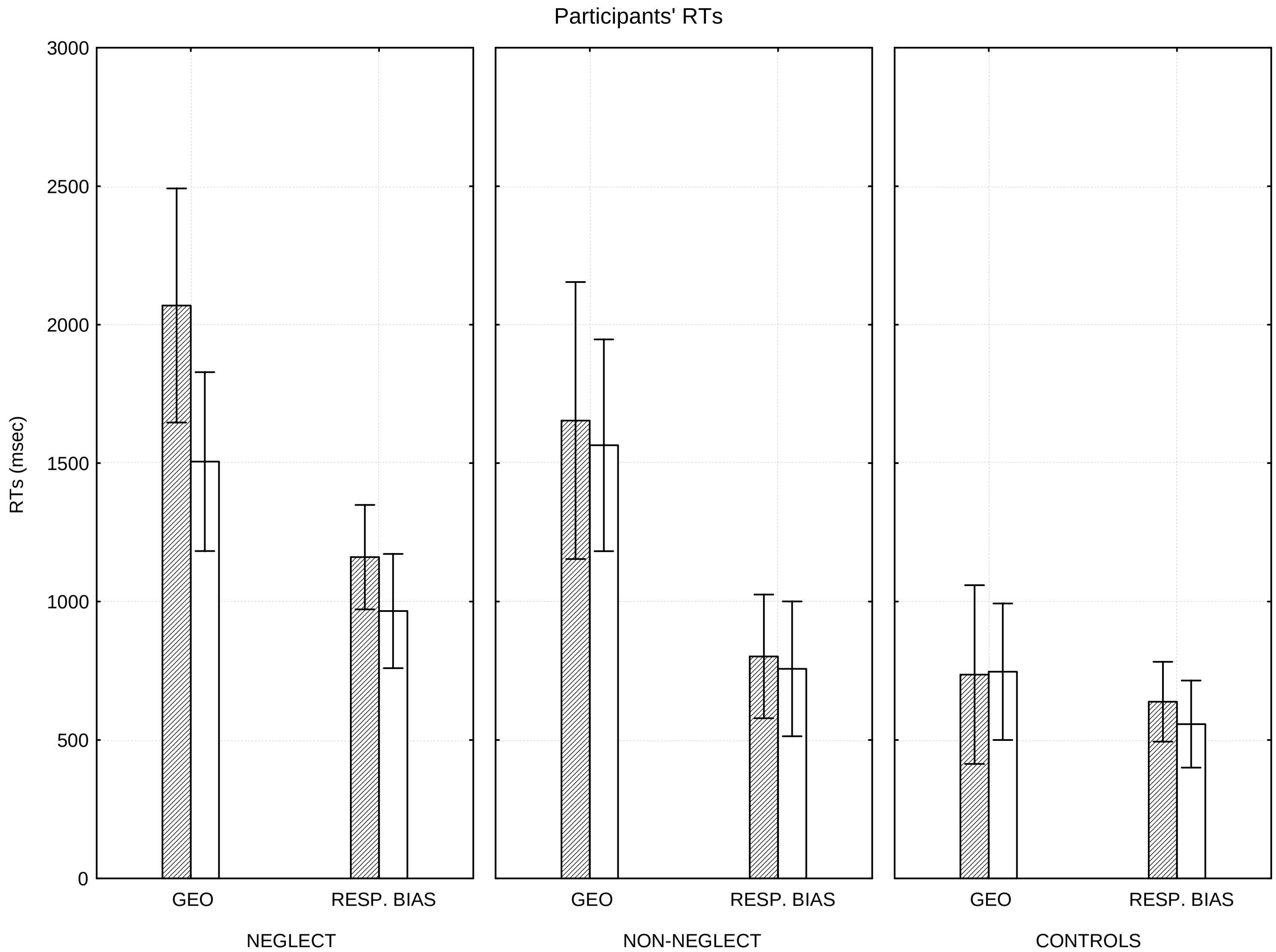
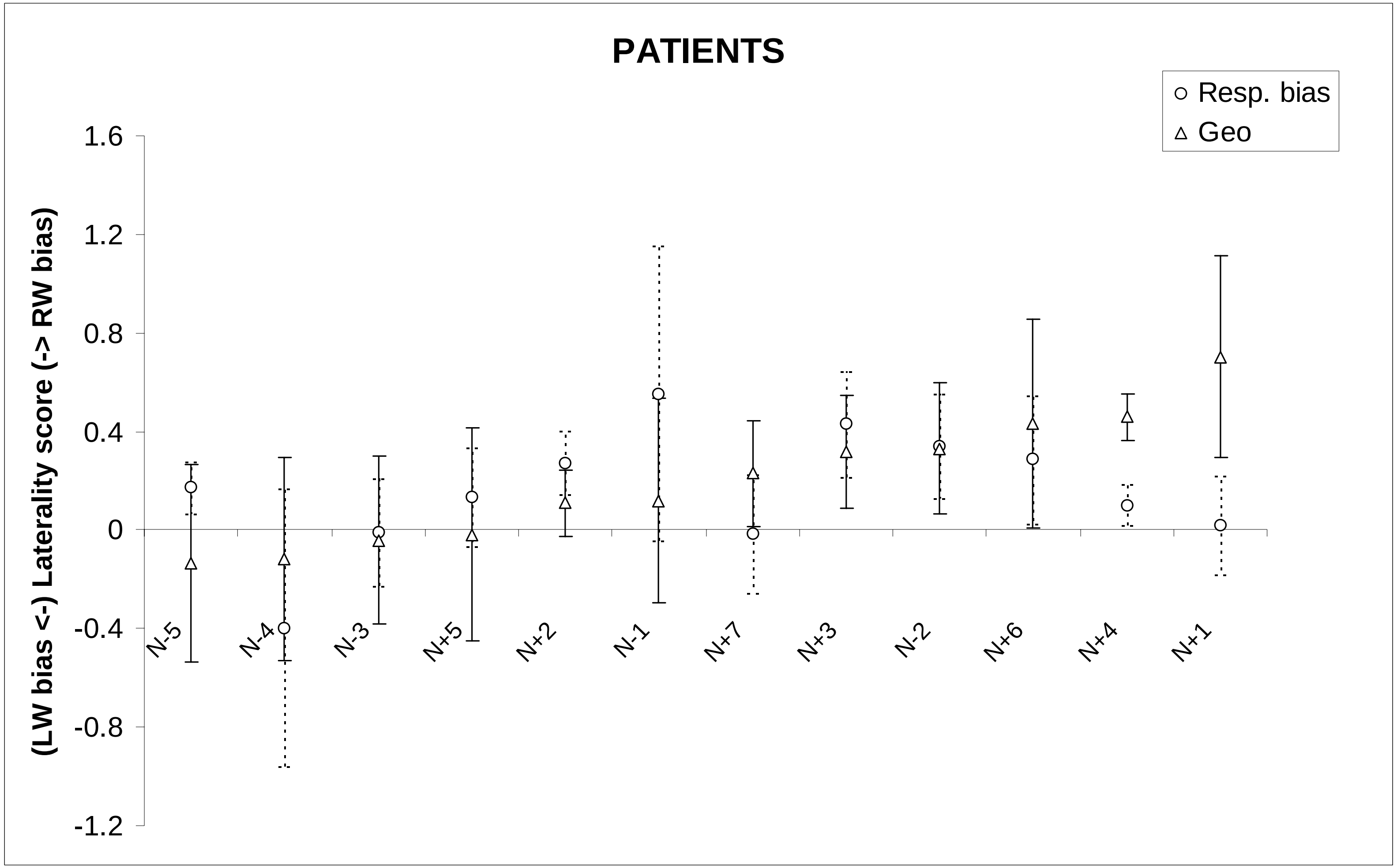

Participants' RTs
RTs (msec)
3000
2500
2000
1500
1000
500
0
GEO
RESP. BIAS
GEO
RESP. BIAS
GEO
RESP. BIAS
NEGLECT
NON-NEGLECT
CONTROLS

Figure 3


PATIENTS
Resp. bias
Geo
(LW bias <-) Laterality score (-> RW bias)
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
N-5
N-4
N-3
N+5
N+2
N-1
N+7
N+3
N-2
N+6
N+4
N+1